Doppler Radar Interpretation

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Weather Radar and You

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Mississippi, Arkansas, and Tennessee rank in the top ten nationally in terms of casualties (deaths/injuries) from tornadoes.

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Radar 101 - The Fundamentals of Doppler Radar

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NEXRAD (**Nex**t Generation **Rad**ar) obtains weather information (precipitation and wind) based upon returned energy. The radar emits a burst of energy . If the energy strikes an object (rain drop, bug, bird, etc), the energy is scattered in all directions. A small fraction of that scattered energy is directed back toward the radar.

This reflected signal is then received by the radar during its listening period. Computers analyze the strength of the returned pulse and time it took to travel to the object and back. This process of emitting a signal, listening for any returned signal, then emitting the next signal, takes place very fast, up to around 1300 times each second.

NEXRAD spends the vast amount of time "listening" for returning signals it sent. When the time of all the pulses each hour are totaled (the time the radar is actually transmitting), the radar is "on" for about 7 seconds each hour. The remaining 59 minutes and 53 seconds are spent listening for any returned signals.

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The Doppler effect was named after the Austrian physicist, Christian Doppler, who discovered it. You have most likely experienced the "Doppler effect" around trains.

The same effect takes place in the atmosphere as a pulse of energy from the radar strikes an object and is reflected back toward the radar. The radar's computers measure the reflected pulse of energy which then convert that change to a velocity of the object, either toward or away from the radar. Inbound (toward the radar) motion is denoted by green and outbound (away from the radar) is denoted by red. Information on the movement of objects either toward or away from the radar can be used to estimate the speed of the wind. This ability to "see" the wind is what enables the National Weather Service to detect the formation of tornados which, in turn, allows us to issue tornado warnings with more advanced notice.

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While the radar was showing a strong counter-clockwise rotation (previous slide), an F4 tornado (winds > 205 mph) was occurring over northeast Arkansas on January 21, 1999.

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The radar revolves 360 degrees starting at 0.5° above horizontal, scanning the atmosphere for precipitation and wind. The radar then scans at 1.5° , 2.5° up through 19.5°. As the beam spreads out from the radar, the beam rises in altitude since the beam travels in a straight line and the earth's surface is curved. This volume scan will take 5 to 6 minutes.

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Doppler Radar on the Net

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There are 115 National Weather Service (NWS) offices across the country which operate a Doppler radar. In addition to the NWS radars, there are a number of Doppler radars operated by the Department of Defense which are used in conjunction with the NWS. This maps shows the continuous coverage offered by the Doppler radar network.

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This is a display of echo intensity (reflectivity) measured in **dBZ** (decibels of Z, where Z represents the energy reflected back to the radar). "Reflectivity" is the amount of transmitted power returned to the radar receiver. Base Reflectivity images are available at several different elevation angles (tilts) of the antenna and are used to detect precipitation, evaluate storm structure, locate atmospheric boundaries and determine hail potential.

The base reflectivity image is from the lowest "tilt" angle (0.5°). This means the radar's antenna is tilted 0.5° above the horizon. The maximum range of the base reflectivity product is 124 nm (about 143 miles) from the radar location. This view will not display echoes that are more distant than 124 nm, even though precipitation may be occurring at greater distances

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The radar loop is simply a collection of 0.5° base reflectivity images looped to show the previous hour of precipitation movement.

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Like the Short Range Base Reflectivity, the Long Range will go out to distances of 240 nm, but show less detail at farther ranges since the beam is shooting high up into the atmosphere and missing the lower parts of the storm.

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Composite Reflectivity is the maximum echo intensity (reflectivity) from any elevation angle at every range from the radar. This product is used to reveal the highest reflectivity in all echoes. When compared with Base Reflectivity, the Composite Reflectivity can reveal important storm structure features and intensity trends of storms.

The maximum range of the composite reflectivity product is 248 nm (about 285 miles) from the radar location. The blocky appearance of this product is due to its lower spatial resolution on a 2.2 x 2.2 nm grid. It has one-fourth the resolution of the Base Reflectivity and one-half the resolution of the Precipitation products.

Although the Composite Reflectivity product is able to display maximum echo intensities 248 nm from the radar, the beam of the radar at this distance is at a very high altitude in the atmosphere. Thus, only the most intense convective storms and tropical systems will be detected at the longer distances. Because of this fact, special care must be taken interpreting this product. While the radar image may not indicate precipitation it's quite possible that the radar beam is overshooting precipitation at lower levels, especially at greater distances.

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This is an image of estimated one-hour precipitation accumulation. This product is used to assess rainfall intensities for flash flood warnings, urban flood statements and special weather statements. The maximum range of this product is 124 nm (about 143 miles) from the radar location. This product will not display accumulated precipitation more distant than 124 nm, even though precipitation may be occurring at greater distances.

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This image is of estimated accumulated rainfall, continuously updated, since the last one-hour break in precipitation. This product is used to locate flood potential over urban or rural areas, and provide rainfall accumulations for the duration of the event.

The maximum range of this product is 124 nm (about 143 miles) from the radar location. This product will not display accumulated precipitation more distant than 124 nm, even though precipitation may be occurring at greater distances.

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When precipitation is occurring, the radar does not need to be as sensitive as in clear air mode as rain provides plenty of returning signals. At the same time, meteorologists want to see higher in the atmosphere when precipitation is occurring to analyze the vertical structure of the storms. This is when the meteorologists switch the radar to precipitation mode using one of two volume coverage patterns (VCP). The radar continuously scans the atmosphere by completing volume coverage patterns. A VCP consists of the radar making several 360° scans of the atmosphere, sampling a set of increasing elevation angles.

Both precipitation VCP's begin the volume scan at the 0.5° elevation angle, then go to the 1.5° angle and up through 19.5°. The time it takes to complete the entire volume scan is five to six minutes. Differences in the quality of radar images between the two precipitation mode VCPs are relatively minor. Therefore, during severe weather, the faster VCP is almost always used as it provides the meteorologists with the quickest updates and most elevation slices through the storms.

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In clear air mode, the radar is in its most sensitive operation. This mode has the slowest antenna rotation rate which permits the radar to sample a given volume of the atmosphere longer. This increased sampling increases the radar's sensitivity and ability to detect smaller objects in the atmosphere than in precipitation mode. A lot of what you will see in clear air mode will be airborne dust and particulate matter. Also, snow does not reflect energy sent from the radar very well. Therefore, clear air mode will occasionally be used for the detection of light snow.

In clear air mode, the radar begins a volume scan at the 0.5° elevation angle (i.e., the radar antenna is angled 0.5°/ above the ground). Once it makes two full sweeps at the 0.5°/ elevation angle, it increases to 1.5°/ and makes two more 360° rotations. At the higher elevations (2.5°, 3.5°, and 4.5°) a single sweep is made. In clear air mode, the complete scan of the atmosphere takes about 10 minutes.

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The colors are the different echo intensities (reflectivity) measured in dBZ (decibels of Z) during each elevation scan. "Reflectivity" is the amount of transmitted power returned to the radar receiver. Reflectivity (designated by the letter Z) covers a wide range of signals (from very weak to very strong). So, a more convenient number for calculations and comparison, a decibel (or logarithmic) scale (dBZ), is used.

The dBZ values increase as the strength of the signal returned to the radar increases. Each reflectivity image you see includes one of two color scales. One scale (far left) represents dBZ values when the radar is in clear air mode (dBZ values from -28 to +28). The other scale (near left) represents dBZ values when the radar is in precipitation mode (dBZ values from 5 to 75). ***Notice the color on each scale remains the same in both operational modes, only the values change.*** The value of the dBZ depends upon the mode the radar is in at the time the image was created.

The scale of dBZ values is also related to the intensity of rainfall. Typically, light rain is occurring when the dBZ value reaches 20. The higher the dBZ, the stronger the rain rate. Depending on the type of weather occurring and the area of the U.S., forecasters use a set of rain rates which are associated to the dBZ values. These values are estimates of the rainfall per hour, updated each volume scan, with rainfall accumulated over time. Hail is a good reflector of energy and will return very high dBZ values.

Since hail can cause the rainfall estimates to be higher than what is actually occurring, steps are taken to prevent these high dBZ values from being converted to rainfall.

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The Fundamentals of Radar Meteorology

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Squall lines are one type of severe weather phenomena that occur often across the U.S.. This process begins as a single storm and evolves into a linear line of storms over time. Ahead of the squall line there will be warm and moist air that is moving into the line while behind the line is rain cooled air. At the interface of these two air masses is a cloud formation called a shelf cloud which appears as a wedge hanging down on the front side of the thunderstorms (depicted by the yellow arrow). Sometimes in the downdraft area of the squall line, another phenomena called a downburst occurs where the winds accelerate downward causing severe wind damage at the surface. Winds can approach 150 mile an hour in some cases.

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This is a radar picture depicting a squall line that is moving east toward Tennessee. Notice the areal extent of the squall line from southern Arkansas north into southern Missouri. Sometimes a squall line may reach speeds of 60 miles an hour.

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Sometimes a phenomena occurs where the winds a few thousand feet above the surface descend behind the squall line and cause part of the line to accelerate and bow out ahead of the rest of the squall line. This phenomena is called a bow echo and can cause severe wind damage.

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This is a radar picture depicting a bow echo along a squall line where the strongest winds will be at the apex of the bow echo.

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Here are damage photos from straight line winds that were caused by a bow echo. Sometimes the damage is so severe that people will mistake it for tornadic damage.

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Another type of severe weather phenomena is called the supercell. This type of storm is very organized and long lasting. These are the storms that usually produce tornadoes and cause most of the severe damage. A feature called a hook echo can be seen above the yellow arrow and is the area of the storm where a tornado would form. In the storm where the higher reflectivity is depicted (red/orange), one would see the heavy rain and hail.

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Within the family of supercells, a type called the heavy precipitation (HP) supercell is predominate mostly in the southern U.S.. Because of the presence of more precipitation which wraps around the hook echo part of the storm, the hook is not always visible on radar. This is evident where the HP supercell to the left of the yellow arrow does not exhibit a hook echo. This storm produced an F3 tornado.

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In this picture we are looking at what is called an outflow or gust front. This occurs when the rain cooled air from the downdraft of the storm moves out from the storm. The dBZ return will usually be in the 5 dBZ to 10 dBZ range but can by as high as 20 dBZ when the there is a lot of moisture present in the atmosphere. The radar is helpful in that the meteorologist can look for areas where two gust fronts will collide and possibly form new thunderstorms. This is important during flash flood situations.

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The End